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Chemistry 20 ▮ 30
Program of Studies

Chemistry 20	is approved with interim status for the 1993–1994 school year.
Chemistry 30	is in field validation for the 1993–1994 school year.

Curriculum Branch

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CHEMISTRY 20–30

A. PROGRAM RATIONALE AND PHILOSOPHY

Chemistry is the study of matter and its changes. Through the study of chemistry, the learners are given an opportunity to explore and understand the natural world and to become aware of the profound influence of chemistry in their lives. Meaningful learning is facilitated by relating the study of chemistry to what the learners already know, deem personally useful and consider relevant. Learning proceeds best when it originates from a base of concrete experiences presenting an authentic view of science in the context of chemistry. In Chemistry 20–30, students learn chemistry in relevant contexts and engage in meaningful activities. This facilitates the transfer of knowledge to new contexts. Students are encouraged to participate in lifelong learning about chemistry and to appreciate chemistry as a scientific endeavour with practical impact on their own lives and on society as a whole.

Chemistry, as with all sciences, is an experimental discipline requiring creativity and imagination. Methods of inquiry characterize its study. In Chemistry 20–30, students further develop their ability to ask questions, investigate and experiment; to gather, analyze and assess scientific information; and to test scientific laws and principles and their applications. In the process, students exercise their creativity and develop critical thinking skills. Through experimentation, problem-solving activities and independent study, students develop an understanding of the processes by which scientific knowledge evolves.

The Chemistry 20–30 program places students at the centre. Students are active learners and will assume increased responsibility for their learning as they work through the program. A thorough study of chemistry is required to give students an understanding of the discipline that encourages them to make appropriate applications of scientific concepts to their daily lives and prepares them for future studies in chemistry. Students are expected to participate actively in their own learning; teachers act as collaborators or guides. An emphasis on the key concepts and principles of chemistry provides students with a more unified view of the sciences and a greater awareness of the connections among them.

These science learnings will take varying amounts of time to acquire, depending on the individual learning styles and abilities of students. While each course is designed for approximately 125 hours, teachers are encouraged to modify the amount of instructional time to meet the individual needs of students. Some students will require more than 125 hours, while others will require less.

GOALS

The major goals of the Chemistry 20–30 are:

- to develop in students an understanding of the big interconnecting ideas and principles that transcend and unify the natural science disciplines

- to provide students with an enhanced understanding of the scientific world view, inquiry and enterprise

- to help students attain the level of scientific awareness essential for all citizens in a scientifically literate society

- to help students make informed decisions about further studies and careers in science

- to provide students with opportunities for acquiring attitudes, knowledge and skills that contribute to personal development.

Chemistry 20–30 is an academic program that helps students better understand and apply fundamental concepts and skills. The focus is on helping students understand the chemistry principles behind the natural events they experience and the technology they use in their daily lives. The program encourages enthusiasm for the scientific enterprise and develops positive attitudes about chemistry as an interesting human activity with personal meaning. It develops in students the attitudes, knowledge and skills to help them become capable of, and committed to, setting goals, making informed choices and acting in ways that will improve their own lives and life in their communities.

B. GENERAL LEARNER EXPECTATIONS

The general learner expectations outline the many facets of scientific awareness and serve as the foundation for specific learner expectations. The general learner expectations are developed through the study of individual units in Chemistry 20–30 and, though listed sequentially, are not meant to be developed sequentially or separately.

ATTITUDES

Students will be encouraged to develop:

- an enthusiasm for, and a continuing interest in, science
- the effective attributes of scientists at work; such as, respect for evidence, tolerance of uncertainty, intellectual honesty, creativity, perseverance, cooperation, curiosity and a desire to understand
- positive attitudes toward scientific skills involving mathematics, problem solving and process skills
- open-mindedness and respect for the points of view of others
- a sensitivity to the living and non-living environment
- an appreciation for the roles of science and technology in our understanding of the natural world.

KNOWLEDGE

Science Themes

Students will be expected to demonstrate an understanding of themes that transcend the discipline boundaries, and show the unity among the natural sciences, including:

- Change: how all natural entities are modified over time, how the direction of change might be predicted and, in some instances, how change can be controlled
- Diversity: the array of living and non-living forms of matter and the procedures used to understand, classify and distinguish those forms on the basis of recurring patterns
- Energy: the capacity for doing work that drives much of what takes place in the Universe through its variety of interconvertible forms
- Equilibrium: the state in which opposing forces or processes balance in a static or dynamic way
- Matter: the constituent parts, and the variety of states of the material in the physical world
- Systems: the interrelated groups of things or events that can be defined by their boundaries and, in some instances, by their inputs and outputs.

SKILLS

Students will be expected to develop an ability to use thinking processes associated with the practice of science for understanding and exploring natural phenomena, problem solving and decision making. These processes involve many skills that are to be developed within the context of the program content.

The skills framework presented here assumes that thinking processes often begin with an unresolved problem or issue, or an unanswered question. The problem, issue or question is usually defined and hypotheses formulated before information gathering can begin. At certain points in the process, the information

needs to be organized and analyzed. Additional ideas may be generated—for example, by prediction or inference—and these new ideas, when incorporated into previous learning, can create a new knowledge structure. Eventually, an outcome, such as a solution, an answer or a decision is reached. Finally, criteria are established to judge ideas and information in order to assess both the problem-solving process and its outcomes.

The following skills are not intended to be developed sequentially or separately. Effective thinking appears to be non-linear and recursive. Students should be able to access skills and strategies flexibly; select and use a skill, process or technology that is appropriate to the task, and monitor, modify or replace it with a more effective strategy.

- Initiating and Planning
  - identify and clearly state the problem or issue to be investigated
  - differentiate between relevant and irrelevant data or information
  - assemble and record background information
  - identify all variables and controls
  - identify materials and apparatus required
  - formulate questions, hypotheses and/or predictions to guide research
  - design and/or describe a plan for research, or to solve a problem
  - prepare required observation charts or diagrams
- Collecting and Recording
  - carry out the procedure and modify, if necessary
  - organize and correctly use apparatus and materials to collect reliable experimental data
  - accurately observe, gather and record data or information according to safety regulations; e.g., Workplace Hazardous Materials Information System (WHMIS), and environmental considerations
- Organizing and Communicating
  - organize and present data (themes, groups, tables, graphs, flow charts and Venn diagrams) in a concise and effective form
  - communicate data more effectively, using mathematical and statistical calculations, where necessary
  - express measured and calculated quantities to the appropriate number of significant digits, using SI units for all quantities
  - communicate findings of investigations in a clearly written report
- Analyzing
  - analyze data or information for trends, patterns, relationships, reliability and accuracy
  - identify and discuss sources of error and their affect on results
  - identify assumptions, attributes, biases, claims or reasons
  - identify main ideas
- Connecting, Synthesizing and Integrating
  - predict from data or information
  - formulate further testable hypotheses supported by the knowledge and understanding generated
  - identify further problems or issues to be investigated
  - identify alternatives for consideration
  - propose and explain interpretations or conclusions
  - develop theoretical explanations
  - relate the data or information to laws, principles, models or theories identified in background information
  - propose solutions to a problem being investigated
  - summarize and communicate findings
  - decide on a course of action
- Evaluating the Process or Outcomes
  - establish criteria to judge data or information
  - consider consequences and perspectives
  - identify limitations of the data or information, and interpretations or

conclusions, as a result of the experimental/research/project/design process or method used
- suggest alternatives and consider improvements to experimental technique and design
- evaluate and assess ideas, information and alternatives

Further Reading

For a more detailed discussion on how to integrate thinking and research skills into the science classroom, refer to the Alberta Education publications: *Teaching Thinking: Enhancing Learning* (1990) and *Focus on Research: A Guide to Developing Students' Research Skills* (1990).

CONNECTIONS AMONG SCIENCE, TECHNOLOGY AND SOCIETY

Science, Technology and Society (STS)

Students will be expected to demonstrate an understanding of the processes by which scientific knowledge is developed, and of the interrelationship of science, technology and society, including:

- the central role of experimental evidence in the accumulation of knowledge, and the way in which proposed theories may be supported, modified or refuted
- the inability of science to provide complete answers to all questions
- the functioning of products or processes based on scientific principles
- the ways in which science advances technology and technology advances science
- the use of technology to solve practical problems
- the limitations of scientific knowledge and technology
- the influence of the needs, interests and financial support of society on scientific and technological research
- the ability and responsibility of society, through science and technology, to protect the environment and use natural resources judiciously to ensure quality of life for future generations.

Further Reading

For further reading on integrating science, technology and society into the classroom, refer to the Alberta Education publication: *STS Science Education: Unifying the Goals of Science Education* (1990).

C. SPECIFIC LEARNER EXPECTATIONS

LEARNING CYCLE

The specific learner expectations consist of the attitudes, knowledge and skills that are to be addressed in Chemistry 20–30. The use of the learning cycle allows students to progress from:

- an introduction framing the lesson in an STS connection relevant to the lives of the learners, and makes connections between past and present learning experiences, as well as anticipates activities to focus students' thinking on the learning outcomes of the activity, to
- the experiential exploration of new content that provides students with a common base of experiences within which they identify and develop key concepts, processes and skills, through
- a hypothesis-building phase where concepts are developed to describe a particular aspect of their experiential exploration, and opportunities are provided to communicate their conceptual understanding, or demonstrate their skills or behaviours, to
- an elaboration phase that extends understanding of key concepts and allows further opportunities to practise desired skills and problem-solving strategies, to
- an application phase where the hypothesis, vocabulary and patterns previously developed are applied to new situations and related to key concepts and principles of science, to
- a final evaluation of the significance of the new learning in an STS context to assess their understanding and abilities, and provide opportunities for teachers to evaluate student progress toward achieving the educational objectives.

In chemistry, students examine phenomena in a variety of topics to show the relationships among the sciences. Wherever possible, examples should be framed in the context of the learners' own experiences to enable them to make the connections between scientific knowledge and the society around them, the technology that societies have developed, and the nature of science itself.

PROGRAM OVERVIEW

The Chemistry 20–30 program emphasizes the science themes: *change, diversity, energy, equilibrium, matter* and *systems,* as they relate to chemistry. These themes provide a means of showing the connections between the units of study in both courses of the program, and provide a framework for teachers to show students how individual sections of the program relate to the big ideas of science.

In addition to developing a solid understanding of the fundamental science concepts and principles, Chemistry 20–30 has the goal of educating students about the nature of science and technology, and the interaction between chemistry and technology. Students must be aware of the tremendous impact of chemistry and associated technology on society, but at the same time they must be aware of the roles and limitations of the chemistry sciences, sciences in general, and of technology in problem solving in a societal context.

CHEMISTRY 20

Matter and chemical *change* are the themes common to all the units in Chemistry 20. An understanding of the nature of *matter* and an analysis of its *changes* is essential for understanding what is happening and for predicting what will happen; control of *change* is essential for the design of technological *systems.* The principles of conservation of mass and *energy* help to predict and explain the *changes* that occur in a closed *system.* Chemistry 20 students are developmentally ready to begin defining *matter* in conceptual terms. Observations that provide evidence to support

theories are stressed through experimentation, and linking empirical and theoretical knowledge.

Chemistry 20 consists of four units of study:

Unit 1: Matter as Solutions, Acids, Bases and Gases
Unit 2: Quantitative Relationships in Chemical Changes
Unit 3: Chemical Bonding in Matter
Unit 4: The Diversity of Matter: An Introduction to Organic Chemistry.

Each unit in Chemistry 20 uses a different context to investigate the nature of *matter*; to identify common patterns and the processes by which *matter* and *systems* are modified. Unit 1 focuses on the nature of *matter*, specifically solutions and gases, by examining their properties, identifying patterns and analyzing *changes*. In Unit 2, the quantitative relationships in chemical reactions are explored in predicting masses of substances reacted or produced as a result of chemical *change*. In Unit 3, models of the atom are extended to models of bonding as the properties of *matter* and theoretical explanations about its behaviour are linked. In Unit 4, organic compounds are investigated and compared with inorganic *matter*. *Change* as it relates to chemical reactions of organic compounds in living and non-living systems is also examined.

CHEMISTRY 30

The themes of *systems*, *energy* and *change* are central in Chemistry 30. *Equilibrium* and *matter* are subordinate themes that are also addressed. The components of a *system*, which may be a collection of substances or processes, influence each other by the transfer of *energy* and *matter*. Changes to one part result in *changes* to other parts of the system. In a system at *equilibrium*, opposing reactions are balanced.

The major concepts allow connections to be drawn among the four units of the course and among all seven units in the two courses in the program.

Chemistry 30 consists of three units of study:

Unit 1: Thermochemical Changes
Unit 2: Electrochemical Changes
Unit 3: Equilibrium, Acids and Bases in Chemical Changes.

Chemistry 30 expands upon the concepts and skills introduced in Science 10 and Chemistry 20. Each unit in Chemistry 30 uses a different context to investigate the nature of chemical *change*. The themes are addressed using examples from inorganic and organic chemistry to emphasize the unity of science. *Energy*, as it relates to chemical *change*, is the focus of Unit 1. *Energy* in the form of heat is most commonly absorbed or released in chemical reactions. Thermochemistry is the study of these heat *changes*. *Changes* in physical and nuclear *systems* are briefly explored for comparison. In Unit 2, electrochemical *systems* are examined, oxidation–reduction reactions are analyzed, and the *matter* and *energy* involved are quantified. In Unit 3, the focus is on chemical *systems* at *equilibrium*. Few chemical reactions proceed in only one direction; most are somewhat reversible. Chemical *systems* involving acids and bases are studied as examples.

CHEMISTRY 20

UNIT 1
MATTER AS SOLUTIONS, ACIDS, BASES AND GASES

OVERVIEW

Science Themes: *Matter, Change* and *Systems*

In Unit 1, students gain an insight into the nature of *matter* through an investigation of *change* in the context of solutions, including acids, bases and gases. Viewing models of *matter* as *systems* undergoing *change* aids in their understanding of the underlying structure of *matter.*

This unit builds on Science 8, Unit 1: Solutions and Substances; Science 9, Unit 5: Chemical Properties and Changes; and on Science 10, Unit 3: Matter and Energy in Chemical Change. It provides students with a foundation for the study of stoichiometry and bonding in Chemistry 20 and electrochemistry, acids and bases in Chemistry 30.

The three **major concepts** developed in this unit are:

- solutions are homogeneous mixtures of pure substances
- acids and bases have an effect on aqueous *systems*
- a model of the gaseous state of *matter* provides insight into molecular behaviour.

In this unit, *students will* develop an ability to use the **skills** and **thinking processes** associated with the practice of science, emphasizing:

- initiating and planning
- collecting and recording data according to safety and environmental considerations
- organizing and communicating data
- evaluating the design of investigations into the properties of and changes to *matter.*

The **STS connections** in this unit illustrate:

- the central role of experimental evidence in the accumulation of knowledge and the way in which proposed theories may be supported, modified or refuted
- the functioning of products or processes based on scientific principles
- the ability and responsibility of society, through science and technology, to protect the environment and use natural resources judiciously to ensure quality of life for future generations.

ATTITUDES

Students will be encouraged to:

- develop a questioning attitude and a desire to understand more about matter
- appreciate that scientific evidence is the foundation for generalizations and explanations about matter
- develop an awareness of the importance of water as a medium for chemical change
- value the need for safe handling and disposal of chemicals
- respect the usefulness of models and theories that are used to explain natural phenomena relating to the behaviour of gases
- develop an interest in the role of solutions, acids, bases and gases in daily life
- appreciate that our understanding of matter has been enhanced by the evidence obtained from the application of technology, particularly instruments for making measurements and managing data.

MAJOR CONCEPTS	KNOWLEDGE
	Students should be able to demonstrate an understanding that:

1. Solutions are homogeneous mixtures of pure substances.	• the composition of solutions can be accurately described, by extending from Science 8, Unit 1, and Science 10, Unit 3, the meaning of solute, solvent, dissolving, solution, solubility, and by:
	  • providing examples, from living and non-living systems, of how dissolving substances in water is a prerequisite for chemical change
	  • differentiating between electrolytes and nonelectrolytes
	  • using a chart of solubility to determine if an ionic compound will dissociate in solution
	  • defining concentration in moles per litre
	  • comparing different ways of expressing concentration; e.g., per cent, parts per million (ppm)
	  • outlining the steps required to prepare a solution or a dilution of a solution
	  • describing an equilibrium system in a saturated solution in terms of equal rates of dissolving and crystallization.

SKILLS	STS CONNECTIONS
Students should be able to demonstrate the skills and thinking processes associated with the practice of science by:	*Students should be able to demonstrate an understanding of the processes by which scientific knowledge is developed and of the interrelationships of science, technology and society by; among other activities:*
• using a simple conductivity apparatus to perform an experiment to identify solutions • using a balance and volumetric glassware to prepare solutions of specified concentration • performing an experiment to determine the identity of an ion, using simple qualitative tests, such as solution colour, flame colour and solubility • writing dissociation equations for dissolved substances, paying attention to qualitative solubility generalizations • calculating, from empirical data, the concentration of solutions in moles per litre and determining mass or volume from such concentrations • calculating, from empirical data, the concentration of diluted solutions, and the quantities of a solution and water to use when diluting • using empirical data and dissociation equations to calculate the concentration of ions in a solution.	• providing examples of how solutions and solution concentrations are applied in technology, in environmental studies and in daily life • comparing the ways in which concentrations of solutions are expressed in the chemistry laboratory, in industry, in household products and in environmental studies • explaining the significance of concentration in risk/benefit analysis • explaining the significance of biological magnification in increasing the concentration of substances in ecosystems • evaluating the risk involved in safe handling, storing and disposing of solutions in common use in the laboratory and in the home • investigating the application of qualitative analysis in the practice of chemistry.

MAJOR CONCEPTS	KNOWLEDGE
	Students should be able to demonstrate an understanding that:

2. Acids and bases have an effect on aqueous systems.	• acids and bases affect the chemistry of aqueous systems, by extending from Science 9, Unit 5, and Science 10, Unit 3, the properties, formulas and names of acids and bases, and by:
	  • defining acids and bases, dissociation and neutralization, empirically and theoretically based on Arrhenius' concepts
	  • defining pH in terms of whole number powers of 10
	  • describing the relationship between pH and hydrogen ion concentration; i.e., a change of 1 in the pH value is equivalent to a ten-fold change in the hydrogen ion concentration
	  • calculating pH values from concentration.

SKILLS	STS CONNECTIONS
Students should be able to demonstrate the skills and thinking processes associated with the practice of science by:	*Students should be able to demonstrate an understanding of the processes by which scientific knowledge is developed and of the interrelationships of science, technology and society by; among other activities:*
• using indicators, pH and conductivity to perform experiments to differentiate among acidic, basic and neutral solutions	• providing examples of how technology uses acids and bases; e.g., pulp and paper, car batteries, food, cleaning aids
• writing dissociation equations and calculating concentrations of H^+ or OH^- for strong acids and bases	• identifying some everyday instances that require knowledge of how to handle acids and bases; e.g., sulfuric acid in car batteries, never mixing bleach with household cleaners, treating accidental acid or base spill, using dilution and/or neutralization
• constructing a table comparing pH and hydrogen ion concentration in order to illustrate that as the hydrogen ion concentration increases, the pH decreases.	• assessing, qualitatively, the risks and benefits of transporting acidic and caustic substances in populated areas
	• comparing the pH scale to others like the Richter scale for measuring the intensity of earthquakes.

MAJOR CONCEPTS	KNOWLEDGE
	Students should be able to demonstrate an understanding that:

3. A model of the gaseous state of matter provides insight into molecular behaviour.	• the behaviour of gases has been extensively described, and relationships quantified by extending from Science 10, Unit 4, the kinetic molecular theory and how it accounts for the properties of solids, liquids and gases, and by:
	  • illustrating how Boyle's and Charles's laws are related to the combined gas law
	  • relating Boyle's, Charles's and Avogadro's laws to the ideal gas law
	  • describing the behaviour of ideal and real gases in terms of the kinetic molecular theory
	  • performing calculations based on the ideal gas equation, $PV = nRT$.

SKILLS	STS CONNECTIONS
Students should be able to demonstrate the skills and thinking processes associated with the practice of science by:	*Students should be able to demonstrate an understanding of the processes by which scientific knowledge is developed and of the interrelationships of science, technology and society by; among other activities:*
• drawing and interpreting graphs of experimental data that relate pressure and temperature to gas volume • designing and performing an experiment to illustrate the gas laws, identifying and controlling variables • performing and evaluating an experiment to determine molar mass from gaseous volume • using empirical data to do calculations based on the ideal gas law.	• providing examples from daily life illustrating the properties of gases; e.g., breathing, olfaction, weather, scuba diving, ammonia fertilizer, internal combustion engine, steam turbine, hot air balloon, automobile air bag • describing, from a historical perspective, how careful experimentation requiring precise measurements led to the formulation of the gas laws • evaluating the advantages and disadvantages of using compressed gas as fuels; e.g., hydrogen, methane or propane.

UNIT 2
QUANTITATIVE RELATIONSHIPS IN CHEMICAL CHANGES

OVERVIEW

Science Themes: *Change* and *Systems*

In Unit 2, students focus on chemical *change* and the quantitative relationships contained in the balanced chemical equation. Students are required to use mathematical manipulation and stoichiometric principles to predict quantities of substances consumed or produced in chemical reactions. This unit builds on Science 10, Unit 3: Matter and Energy in Chemical Change, and Chemistry 20, Unit 1: Matter as Solutions, Acids, Bases and Gases.

This unit provides students with a foundation for the study of quantitative relationships in thermochemical, electrochemical, and acid and base reactions in Chemistry 30.

The two **major concepts** developed in this unit are:

- balanced chemical equations indicate the quantitative relationships among reactants and products involved in chemical *changes*
- the relationships between amounts of reactants and products in chemical *changes* are used in quantitative analysis.

In this unit, *students will* develop an ability to use the **skills and thinking processes** associated with the practice of science, emphasizing:

- initiating and planning
- collecting and recording
- organizing and communicating
- analyzing data related to quantitative relationships in chemical *change*.

The **STS connections** in this unit illustrate:

- the central role of experimental evidence in the accumulation of knowledge, and the way in which proposed theories may be supported, modified or refuted
- the functioning of products or processes based on scientific principles
- the ways in which science advances technology and technology advances science.

ATTITUDES

Students will be encouraged to:

- develop a positive attitude toward mathematical and scientific process skills
- appreciate the importance of careful laboratory techniques and precise calculations for obtaining accurate results
- develop confidence in their ability to reason mathematically
- value the role of technology, such as calculators and balances in problem solving
- develop an awareness of the relationship between chemical principles and applications of chemistry
- appreciate the need for empirical evidence when interpreting observed phenomena.

MAJOR CONCEPTS	KNOWLEDGE
	Students should be able to demonstrate an understanding that:

1. Balanced chemical equations indicate the quantitative relationships among reactants and products involved in chemical changes.	• the mole ratios in balanced chemical reaction equations provide quantitative information about the substances involved, by extending from Science 10, Unit 3, the balancing of equations, and by:
	  • analyzing chemical equations in terms of atoms, molecules, ionic species and moles
	  • using gravimetric, solutions and gas stoichiometry to predict quantities of products/reactants involved in chemical reactions
	  • using estimation and unit analysis in stoichiometric calculations
	  • explaining stoichiometric calculations, using chemical principles

2. The relationships between amounts of reactants and products in chemical changes are used in quantitative analysis.	• stoichiometric methods are important in quantitative analysis, by:
	  • describing quantitative analysis as using scientific methods to determine the quantity of matter in a sample
	  • using evidence from titration to determine the concentration of a solution
	  • using evidence from precipitation reactions to determine the concentration of ions in solutions
	  • explaining what is meant by limiting species, predicted and experimental yields
	  • explaining quantitative analysis, using chemical principles.

SKILLS	STS CONNECTIONS
Students should be able to demonstrate the skills and thinking processes associated with the practice of science by:	*Students should be able to demonstrate an understanding of the processes by which scientific knowledge is developed and of the interrelationships of science, technology and society by; among other activities:*
• performing experiments to test the validity of assumptions contained in stoichiometry methods by, for example, predicting, then measuring the amount of product obtained from a reaction, and calculating the per cent difference	• analyzing, with stoichiometric methods, the chemical reactions involved in industrial chemical processes; e.g., fertilizer production, Down's cell, Haber–Bosch process, combustion, water treatment, automobile air bags
• using a balance to collect data for stoichiometric experiments	• discussing the role of experimental evidence in supporting or changing scientific theories by, for example, citing Lavoisier's role in disputing the caloric theory
• using a calculator to perform calculations related to stoichiometric experiments	
• using appropriate glassware and equipment to perform an experiment to determine the concentration of a solution	• discussing the interrelationship of science and technology, using examples of how stoichiometry is applied
• performing an experiment based on a precipitation reaction, to determine the concentration of a solution	• describing industrial, commercial and household applications and associated careers that require a knowledge of quantitative analysis
• designing, performing and evaluating an experiment based on methods, such as crystallization, filtration or titration, to determine the concentration of a solution.	• evaluating the significance of specific by-products in industrial, commercial and household applications of chemical reactions in terms of usefulness, recovery and environmental impact; e.g., SO_2 from smokestacks, catalytic afterburners, backwash from swimming pools.

UNIT 3
CHEMICAL BONDING IN MATTER

OVERVIEW

Science Theme: *Matter*

The major focus of this unit is to relate theories about bonding to the properties of matter and to develop explanations and descriptions of structure and bonding through scientific models.

This unit builds on Science 10, Unit 3: Matter and Energy in Chemical Change, and the previous two units of Chemistry 20. This unit provides an introduction to Chemistry 30, Unit 1: Thermochemical Changes, and Unit 2: Electrochemical Changes.

The **major concept** developed in this unit is:

- chemical bonding in *matter* results in the formation of compounds.

In this unit, *students will* develop an ability to use the **skills** and **thinking processes** associated with the practice of science, emphasizing:

- initiating and planning
- collecting and recording
- analyzing
- connecting, synthesizing and integrating while investigating bonding in *matter*.

The **STS connections** in this unit illustrate:

- the central role of experimental evidence in the accumulation of knowledge and the way in which proposed theories may be supported, modified or refuted
- the inability of science to provide complete answers to all questions
- the functioning of products or processes based on scientific principles
- the limitations of scientific knowledge and technology.

ATTITUDES

Students will be encouraged to:

- develop curiosity about the nature of chemical bonding
- appreciate the usefulness of models and theories in helping to explain the structure and behaviour of matter
- value the need for safe handling and disposal of chemicals
- tolerate the uncertainty in our explanations about the nature of matter
- appreciate the restricted nature of evidence when interpreting observed phenomena.

MAJOR CONCEPTS	KNOWLEDGE
	Students should be able to demonstrate an understanding that:

1. Chemical bonding in matter results in the formation of compounds.	• theories about bonding propose that chemical bonds involve electron transfer or sharing, by extending from Science 10, Unit 3, the simple model of the atom, the organization of the periodic table and the differences in properties of ionic and covalent compounds, and by:
	  • defining a chemical bond as resulting from the simultaneous attraction of electrons by two or more atomic nuclei
	  • describing bonding as a continuum ranging from complete electron transfer to equal sharing of electrons
	  • defining valence electron, electronegativity, electron pairing, ionic bond and covalent bond
	  • explaining why formulas for ionic compounds refer to the simplest whole number ratio of ions that results in a net charge of zero, while the formulas for molecular compounds refer to the number of atoms of each constituent element
	  • comparing and contrasting intramolecular bonding with intermolecular forces, simply, in terms of strength and species involved
	  • explaining, in simple terms, the energy changes of bond breaking and bond formation and relating this to why some changes are exothermic while others are endothermic
	  • describing the information contained in the activity series and how it was developed
	  • defining oxidation as a loss of electrons and reduction as a gain of electrons
	  • relating the terms oxidation and reduction to simple interactions between metals and non-metals; e.g., corrosion.

SKILLS	STS CONNECTIONS
Students should be able to demonstrate the skills and thinking processes associated with the practice of science by:	*Students should be able to demonstrate an understanding of the processes by which scientific knowledge is developed and of the interrelationships of science, technology and society by; among other activities:*
• building models depicting the structure of simple covalent molecules and ionic solids	• analyzing how ionic and covalent compounds are significant in daily life by, for example; investigating the composition of household products, combustion reactions and life processes
• using the periodic table as a tool for predicting the formation of ions	• relating chemical bonding theory, oxidation and reduction, and the activity series to commonly used terms, such as "precious" metal, rusting, galvanizing, cathodic protection, stability and reactivity
• writing half-reactions for the formation of simple ionic compounds, showing oxidation of metals and reduction of non-metals; then balancing for charge and combining into a single equation; e.g., $2Na(s) \rightarrow 2Na^+ + 2e^-$ $Cl_{2(g)} + 2e^- \rightarrow 2Cl^-$ $2Na(s) + Cl_{2(g)} \rightarrow 2NaCl_{(s)}$	• discussing the limitations of bonding theories by, for example, investigating bonding in metals and ceramics and the concept of resonance
• designing and performing an experiment to investigate the reactivity of various metals with water, oxygen and dilute acid, to develop an activity series	• relating the properties (e.g., melting and boiling points, solubility, density and viscosity) of common substances to their predicted intramolecular and intermolecular bonding
• using data contained in the periodic table, and the activity series to predict bonding and electron transfer between elements	• interrelating the applications and properties of modern materials, such as semiconductors, ceramics and composites
• drawing electron dot diagrams of atoms and molecules, and using Lewis structures to predict bonding in simple molecules.	• explaining how science and technology interact in the production and distribution of useful materials.

UNIT 4
THE DIVERSITY OF MATTER: AN INTRODUCTION TO ORGANIC CHEMISTRY

OVERVIEW

Science Themes: *Matter, Diversity* and *Change*

In this unit, students learn more about the *diversity of matter* from specific examples of organic compounds. Students are introduced to the chemical and physical properties of organic compounds, the general nomenclature and formulas for hydrocarbon categories, their significant derivatives and reactions. Another theme of the unit is *change* as it relates to chemical reactions involving organic compounds in living and non-living systems.

This unit builds on Science 9, Unit 5: Chemical Properties and Changes; Science 10, Unit 3: Matter and Energy in Chemical Change; and Chemistry 20, Unit 3: Chemical Bonding in Matter. The unit prepares students for the integrated approach to organic and inorganic chemistry that is taken in Chemistry 30.

The two **major concepts** developed in this unit are:

- organic compounds are a common form of *matter*
- the chemical *changes* of organic compounds are many and *diverse*.

In this unit, *students will* develop an ability to use the **skills** and **thinking processes** associated with the practice of science, emphasizing:

- initiating and planning
- organizing and communicating
- connecting, synthesizing and integrating in the investigation of organic compounds and their reactions.

The **STS connections** in this unit illustrate:

- the functioning of products or processes based on scientific principles
- the influence of the needs, interests and financial support of society on scientific and technological research
- the ability and responsibility of society, through science and technology, to protect the environment and use natural resources judiciously to ensure quality of life for future generations.

ATTITUDES

Students will be encouraged to:

- develop an appreciation of the diversity of organic compounds and their significance to daily life
- appreciate that science and technology provide them with many useful products
- value the need for safe handling and disposal of chemicals
- develop an awareness that, as a result of chemistry, synthetic compounds of great benefit to society have been produced
- develop an awareness of the need for open-mindedness in evaluating environmental issues
- respect the contributions and limitations of scientific and technological knowledge to societal decision making.

MAJOR CONCEPTS	KNOWLEDGE
	Students should be able to demonstrate an understanding that:
1. Organic compounds are a common form of matter.	• organic compounds have distinguishing characteristics, by: • comparing organic and inorganic compounds in terms of the presence of carbon, bonding and related properties, relative molecular size and mass, and natural sources • describing the composition and structural formulas for aliphatic, cyclic and aromatic hydrocarbons • providing names and formulas for examples of the organic compounds described above • defining and giving examples of structural isomerism • identifying alcohols, aldehydes, ketones, organic acids, amines, amides and esters from their names and the functional groups in their structural formulas
2. The chemical changes of organic compounds are many and diverse.	• organic compounds undergo a variety of chemical reactions, by: • defining and giving examples of addition, substitution, elimination, esterification and combustion reactions of hydrocarbons • writing and balancing chemical equations for representative reactions of hydrocarbons • defining and outlining the structures of, and providing examples of, monomers, polymers and polymerization in living and non-living systems; e.g., plastics, carbohydrates, proteins • comparing and contrasting reactions of organic compounds in living and non-living systems; e.g., the combustion of fuels and the oxidation of carbohydrates.

SKILLS	STS CONNECTIONS
Students should be able to demonstrate the skills and thinking processes associated with the practice of science by:	*Students should be able to demonstrate an understanding of the processes by which scientific knowledge is developed and of the interrelationships of science, technology and society by; among other activities:*
• using safe substances and procedures to perform an experiment to investigate the physical and chemical properties of representative examples of organic compounds • gathering data to compare the properties of a pair of organic isomers • building molecular models depicting the structures of simple organic compounds	• comparing examples of organic and inorganic compounds and where they are found and how they are used in everyday life • discussing different conventions of nomenclature in a historical and cultural context
• building models depicting polymerization • synthesizing an organic compound; e.g., ethyl alcohol, an ester, a polymer or soap.	• analyzing common polymers in terms of their composition and structure • describing, briefly, the ethylene industry in Alberta • investigating careers related to organic chemistry • assessing the positive and negative effects of synthetically produced organic compounds, recognizing that a practical solution often requires a compromise between competing priorities.

CHEMISTRY 30

UNIT 1
THERMOCHEMICAL CHANGES

OVERVIEW

Science Themes: *Change, Energy* and *Systems*

In this unit, students study *energy* as it relates to physical, chemical and nuclear *changes* and quantify the energy involved in thermochemical systems.

This unit builds on Science 9, Unit 3: Heat Energy: Transfer and Conservation; Science 10, Unit 1: Energy from the Sun, Unit 3: Matter and Energy in Chemical Change, and Unit 4: Energy and Change; and Chemistry 20, Unit 2: Quantitative Relationships in Chemical Changes. This unit prepares students for post-secondary studies in related areas.

The **major concept** developed in this unit is:

- there are *energy* changes associated with *changes* to matter.

In this unit, *students will* develop an ability to use the **skills and thinking processes** associated with the practice of science, emphasizing:

- initiating and planning
- collecting and recording
- organizing and communicating
- analyzing
- connecting, synthesizing, integrating
- evaluating investigations of *energy changes.*

The **STS connections** in this unit illustrate:

- the use of technology to solve practical problems
- the influence of the needs, interests and financial support of society on scientific and technological research
- the ability and responsibility of society, through science and technology, to protect the environment and use natural resources judiciously to ensure quality of life for future generations.

ATTITUDES

Students will be encouraged to:

- develop an interest in the energy transformations happening around them
- appreciate the usefulness of computational competence and problem-solving skills as they relate to energy
- value the need for accuracy and precision in data collection related to energy
- develop a sense of responsibility toward the use of energy
- develop an interest in global energy issues and the effectiveness of local activities in contributing to the solution of problems related to energy
- appreciate the need to balance long-term energy and environmental objectives with various societal needs
- appreciate the significance and meaning of various alternative possible solutions to a problem.

MAJOR CONCEPTS	KNOWLEDGE
	Students should be able to demonstrate an understanding that:
1. There are energy changes associated with changes to matter.	• energy changes can be measured and quantified, by extending from Science 10, Unit 1: Energy from the Sun, and Unit 4: Energy and Change; the law of conservation of energy, the first law of thermodynamics, definitions for potential and kinetic energy, heat of fusion and calculations involving temperature and phase changes in water, as well as extending from Chemistry 20, Unit 3, the meaning of bond energy, exothermic and endothermic change, and by: • explaining what is meant by the energy change of a system • writing balanced reaction equations that include the energy change • using ΔH notation to communicate energy changes • defining molar enthalpy, including the heats of fusion, vaporization, formation, dissolution and reaction • using Hess's law to derive equations for energy changes • explaining how energy stored in fossil fuels originates in the Sun • comparing cellular respiration to the combustion of fuels • comparing phase, chemical and nuclear changes in terms of the magnitudes of the energy involved • providing simple theoretical explanations for the energy changes that occur during phase, chemical and nuclear changes to matter • performing calculations related to energy changes in physical and chemical changes to matter.

SKILLS	STS CONNECTIONS
Students should be able to demonstrate the skills and thinking processes associated with the practice of science by:	*Students should be able to demonstrate an understanding of the processes by which scientific knowledge is developed and of the interrelationships of science, technology and society by; among other activities:*
• drawing and interpreting energy diagrams based on experimental data; e.g., heating curves and potential energy graphs for phase, chemical and nuclear changes • designing, performing and evaluating experiments to determine the molar enthalpies of physical and chemical changes • performing calculations based on empirical data gathered from experiments demonstrating energy changes associated with chemical and physical changes to matter • designing an experimental procedure to determine the molar enthalpy of a nuclear change • designing and constructing a heating device and calculating its efficiency.	• providing examples of their personal reliance on the chemical potential energy of fuels • illustrating the economic importance of fossil fuels, with examples from the petroleum and petrochemical industries in Alberta • analyzing, using chemical principles, the refining of hydrocarbons • evaluating different fuels from the perspective of economic and environmental impact • assessing, qualitatively, the risks and benefits of relying on fossil fuels as an energy source • assessing, qualitatively, the risks and benefits to society of using nuclear energy • investigating careers related to the energy industry • researching and analyzing alternative energy sources • identifying and evaluating ways of using energy more efficiently in the home and community.

UNIT 2
ELECTROCHEMICAL CHANGES

OVERVIEW

Science Themes: *Matter, Energy, Systems* and *Change*

In this unit, students study electrochemical *changes,* analyzing the *matter* and *energy* changes within a *system.*

This unit builds on Science 9, Unit 4: Electromagnetic Systems; Science 10, Unit 3: Matter and Energy in Chemical Change; Chemistry 20, Unit 2: Quantitative Relationships in Chemical Changes, and Unit 3: Chemical Bonding. This unit prepares students for post-secondary study in related areas.

The two **major concepts** developed in this unit are:

- many chemical *changes* involve the transfer of electrons
- *energy* is involved in electrochemical *changes.*

In this unit, *students will* develop an ability to use the **skills and thinking processes** associated with the practice of science, emphasizing:

- initiating and planning
- collecting and recording
- organizing and communicating
- analyzing
- connecting, synthesizing, integrating
- evaluating investigations of electrochemical *change.*

The **STS connections** in this unit illustrate:

- the functioning of products or processes based on scientific principles
- the ways in which science advances technology and technology advances science
- the ability and responsibility of society, through science and technology, to protect the environment and use natural resources judiciously to ensure quality of life for future generations.

ATTITUDES

Students will be encouraged to:

- develop an interest in oxidation–reduction reactions that occur in everyday life
- appreciate the creativity and perseverance required to develop workable solutions to problems
- develop a willingness to try various problem-solving strategies, and risk being wrong
- value the contributions of the technological innovations of electrochemistry to quality of life
- develop an awareness that the application of technology by human societies can have beneficial and harmful effects on biological systems
- appreciate the multi-dimensional nature of science, technology and society issues.

MAJOR CONCEPTS	KNOWLEDGE
	Students should be able to demonstrate an understanding that:
1. Many chemical changes involve the transfer of electrons.	• oxidation–reduction reactions involve a transfer of electrons, by: • defining the terms: oxidation–reduction, oxidizing agent, reducing agent, oxidation number, half-reaction • differentiating between oxidation–reduction reactions and other reactions by identifying half-reactions and changes in oxidation number • relating oxidation–reduction to biochemical processes; e.g., metabolic oxidation of glucose to carbon dioxide • identifying electron transfer, oxidizing agents and reducing agents in oxidation–reduction reactions • writing and balancing equations for oxidation–reduction reactions • defining standard reduction potential and explaining the derivation relative to $E^\circ = 0.00$ volts for the standard hydrogen electrode • calculating E° net (ΔE°) for oxidation–reduction reactions • predicting the spontaneity or non-spontaneity of oxidation–reduction reactions on the basis of calculated E° net (ΔE°) values • comparing and contrasting oxidation–reduction reactions in living and non-living systems • performing calculations to determine quantities of substances involved in oxidation–reduction reactions.

SKILLS	STS CONNECTIONS
Students should be able to demonstrate the skills and thinking processes associated with the practice of science by:	*Students should be able to demonstrate an understanding of the processes by which scientific knowledge is developed and of the interrelationships of science, technology and society by; among other activities:*
• designing, performing then evaluating an experiment for deriving a simple reduction table • using a reduction table as a tool in predicting the outcome of oxidation–reduction reactions • performing an experiment to test predictions about oxidation–reduction reactions with regard to products, spontaneity and ΔE° • selecting the appropriate equipment, and using it correctly, to perform an oxidation–reduction titration experiment to determine unknown concentrations.	• analyzing oxidation–reduction reactions that occur in everyday life; e.g., corrosion metallurgy, respiration, photosynthesis; identifying half-reactions, oxidizing and reducing agents • analyzing oxidation–reduction reactions used in industry and commercially; e.g., pulp and paper bleaching processes, textile bleaching; swimming pool water treatment; food processing; identifying half-reactions, oxidizing and reducing agents • investigating methods for counteracting corrosion.

MAJOR CONCEPTS	KNOWLEDGE
	Students should be able to demonstrate an understanding that:

2. Energy is involved in electrochemical changes.	• electrochemical cells operate on the energy of spontaneous oxidation–reduction reactions, while electrolytic cells require electrical energy to cause non-spontaneous oxidation–reduction reactions to occur, by:
	  • defining and identifying, on a diagram of an electrochemical/electrolytic cell, the following: anode, cathode, anion, cation; as well as salt bridge/porous cup and external circuit for the former and power supply for the latter
	  • predicting and writing balanced equations for reactions at the cathode and the anode of an electrochemical/electrolytic cell
	  • identifying, on a diagram of an electrochemical/electrolytic cell, the flow of electrons, the migration of ions and anions, and mass changes at the electrodes
	  • performing calculations to determine quantities of products formed in an electrochemical/electrolytic cell.

SKILLS	STS CONNECTIONS
Students should be able to demonstrate the skills and thinking processes associated with the practice of science by:	*Students should be able to demonstrate an understanding of the processes by which scientific knowledge is developed and of the interrelationships of science, technology and society by; among other activities:*
• constructing, observing and describing an electrolytic cell, comparing predictions and observations • designing, constructing and measuring the potential of an electrochemical cell, comparing predictions and observations.	• analyzing the interrelationship of science and technology in commercial applications of electrochemical/electrolytic cells; e.g., batteries, electroplating industries • assessing the impact of electrolytic principles on the refining of metals from their ores • comparing and contrasting the energy costs of refining metals from their ores, and of recycling metals • outlining the process by which commonly used metal-based products; e.g., aluminum or "tin" cans, are recycled in their communities • assessing the economic importance of batteries to modern society, and predicting their future prominence • investigating the issue of disposing of used batteries, and proposing alternatives.

UNIT 3
EQUILIBRIUM, ACIDS AND BASES IN CHEMICAL CHANGES

OVERVIEW

Science Themes: *Systems, Change* and *Equilibrium*

In this unit, the concept of *equilibrium* is expanded to a quantitative treatment in reaction *systems* involving ideal gases and acid and base solutions. Students apply stoichiometric methods to titration experiments, further explore indicators and are introduced to buffer *systems.*

This unit builds on Science 8, Unit 1: Solutions and Substances; Science 9, Unit 5: Chemical Properties and Changes; Science 10, Unit 3: Matter and Energy in Chemical Change; Chemistry 20, Unit 1: Matter as Solutions, Acids, Bases and Gases, and Unit 2: Quantitative Relationships in Chemical Changes. This unit prepares students for post-secondary studies in related areas.

The two **major concepts** developed in this unit are:

- there is a balance of opposing reactions in chemical *equilibrium systems*
- acid–base chemistry involves proton transfer.

In this unit, *students will* develop an ability to use the **skills** and **thinking processes** associated with the practice of science, emphasizing:

- initiating and planning
- collecting and recording
- organizing and communicating
- analyzing
- connecting, synthesizing, integrating
- evaluating investigations of *equilibrium*, acids and bases.

The **STS connections** in this unit illustrate:

- the central role of experimental evidence in the accumulation of knowledge and the way in which proposed theories may be supported, modified or refuted
- the functioning of products or processes based on scientific principles
- the limitations of scientific knowledge and technology
- the ability and responsibility of society, through science and technology, to protect the environment and use natural resources judiciously to ensure quality of life for future generations.

ATTITUDES

Students will be encouraged to:

- appreciate the usefulness of the mathematical model in describing chemical equilibrium
- value the role of precise observation and careful experimentation in learning about the chemistry of acids and bases
- tolerate the uncertainty involved in providing theoretical definitions for acids, bases and equilibrium
- value the need for safe handling, storage and disposal of chemicals
- appreciate the complexity of environmental problems, such as acid deposition, that don't have a simple solution
- foster intellectual honesty, open-mindedness and objectivity when assessing environmental effects caused by chemical change.

MAJOR CONCEPTS	KNOWLEDGE
	Students should be able to demonstrate an understanding that:

1. There is a balance of opposing reactions in chemical equilibrium systems.	• chemical reactions involving gases, acids and bases can be described as dynamic equilibrium systems, by extending from Chemistry 20 the definitions for acids, bases and pH, and by:
	  • stating the criteria that apply to a system at equilibrium; e.g., closed, constancy of properties, evidence of reversibility
	  • writing chemical reaction equations for chemical systems at equilibrium
	  • calculating equilibrium constants and concentrations from the equilibrium law expression for homogeneous chemical systems
	  • using Le Chatelier's principle to predict, qualitatively, shifts in equilibrium caused by changes in temperature, pressure, volume or concentration
	  • calculating H_3O^+ and OH^- concentrations, pH and pOH, using the ionization constant for water, Kw
	  • explaining the pH scale in terms of logarithms
	  • differentiating between strength and concentration in acids and bases on the basis of properties
	  • comparing and contrasting strong and weak acids and bases, using equilibrium principles.

SKILLS	STS CONNECTIONS
Students should be able to demonstrate the skills and thinking processes associated with the practice of science by:	*Students should be able to demonstrate an understanding of the processes by which scientific knowledge is developed and of the interrelationships of science, technology and society by; among other activities:*
• designing and performing an experiment to test, qualitatively, predictions of equilibrium shifts • calculating equilibrium constants from provided empirical data • designing and performing an experiment to differentiate among strong and weak acids and bases and other solutions • performing calculations to determine H_3O^+, OH^- concentrations and pOH from measurements of pH.	• applying equilibrium principles to analyze everyday phenomena; e.g., the higher concentration of red blood cells in the circulatory systems of people living at high altitudes; carbon dioxide gas escaping from an open bottle of pop • analyzing, on the basis of equilibrium principles, industrial processes, such as the Haber–Bosch process for producing ammonia.

MAJOR CONCEPTS	KNOWLEDGE
	Students should be able to demonstrate an understanding that:

2. Acid–base chemistry involves proton transfer.	• Brønsted–Lowry acid–base reactions involve proton transfer, by:
	  • writing chemical reaction equations illustrating the Brønsted–Lowry definition of acids and bases
	  • identifying conjugate pairs of Brønsted–Lowry acids and bases in chemical reactions
	  • describing indicators and explaining their colour changes in terms of an equilibrium shift
	  • describing examples of substances that can act as either proton donors or proton acceptors
	  • describing examples of substances that can accept or donate more than one proton
	  • performing calculations related to reactions between strong acids and bases
	  • differentiating between end point and equivalence point
	  • explaining how buffers maintain a relatively constant pH when small amounts of acid or base are added to an aqueous system
	  • providing examples of buffers that operate in living systems.

SKILLS	STS CONNECTIONS
Students should be able to demonstrate the skills and thinking processes associated with the practice of science by:	*Students should be able to demonstrate an understanding of the processes by which scientific knowledge is developed and of the interrelationships of science, technology and society by; among other activities:*
• predicting the most likely acid–base reaction, using tables of relative acid–base strength	• discussing, from a historical perspective, the limitations of acid–base concepts in explaining observed phenomena and the ways in which scientific ideas change; an example of the role of experimental evidence in the accumulation of knowledge
• designing and performing an experiment to compare the reactivity of inorganic and organic acids and bases	• explaining, using chemical principles, the formation of acid deposition, describing its environmental impact and the measures being taken by industries to reduce emissions
• standardizing an acid or base solution, using primary standards	• evaluating the problem of acid deposition, recognizing that a practical solution may require a compromise between competing priorities
• performing a titration experiment and related calculations to determine the concentration of an acid or base solution	• analyzing, on the basis of chemical principles, the application of buffers; e.g., in processing and storage of food.
• using a pH meter and laboratory glassware related to titrations	
• using indicators to determine the pH of an acid or base solution	
• drawing and interpreting titration curve graphs, using data from titration experiments involving strong acids and bases	
• designing, performing and evaluating an experiment to test buffer action.	

D. BASIC LEARNING RESOURCES

Chemistry 20 and Chemistry 30

Jenkins, Frank et al. *Nelson Chemistry*. Scarborough, ON: Nelson Canada, 1993.

ISBN 0176038639

Wilbraham, Antony C. et al. *Addison-Wesley Chemistry*. Canadian edition/International System of Units (SI) edition. Don Mills, ON: Addison-Wesley Publishers Limited, 1993.

ISBN 0201602024

Basic learning resources for the 1976 Chemistry 30 program, as listed in the Learning Resources Distributing Centre *Buyers Guide*, are to be withdrawn August 31, 1994.

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CHEMISTRY 20-30 PROGRAM OF
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